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Designing Shell and Tube Heat Exchangers Using Triply Periodic Minimal Surfaces for Enhanced Heat Transfer Efficiency

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Abstrak

Desain penukar panas shell and tube yang memanfaatkan permukaan minimal triply periodik (TPMS) menghadirkan pendekatan baru untuk mengoptimalkan kinerja perpindahan panas dan efisiensi sistem. Dengan menggabungkan TPMS, struktur geometris dengan luas permukaan minimal, desain penukar panas dapat mencapai peningkatan karakteristik perpindahan panas sekaligus meminimalkan penggunaan material dan penurunan tekanan. Abstrak ini menguraikan langkah-langkah kunci yang terlibat dalam merancang penukar panas seperti itu, termasuk menentukan persyaratan desain, memilih geometri TPMS yang sesuai, merancang tata letak shell and tube, melakukan analisis dinamika fluida komputasi (CFD), dan mengoptimalkan desain,. Meskipun konsep penggunaan TPMS dalam desain penukar panas relatif baru, namun memiliki potensi besar untuk meningkatkan efisiensi perpindahan panas
Kata kunci: *TPMS, Desain penukar panas shell and tube*

Abstract

The design of shell and tube heat exchangers utilizing triply periodic minimal surfaces (TPMS) presents a novel approach to optimize heat transfer performance and system efficiency. By incorporating TPMS, geometric structures with minimal surface area, the heat exchanger design can achieve improved heat transfer characteristics while minimizing material usage and pressure drop. This abstract outlines the key steps involved in designing such a heat exchanger, including determining design requirements, selecting a suitable TPMS geometry, designing the shell and tube layout, conducting computational fluid dynamics (CFD) analysis,and optimizing the design. While the concept of using TPMS in heat exchanger design is relatively new, it holds great potential for enhancing heat transfer efficiency

INTRODUCTION

Heat exchangers are vital components in various industries, facilitating efficient heat transfer between fluids while maintaining optimal operating conditions. Among the different types of heat exchangers, shell and tube configurations are widely employed due to their versatility and effectiveness (Lee, 2010). In recent years, the exploration of innovative design approaches has led to the integration of triply periodic minimal surfaces (TPMS) in shell and tube heat exchanger design, offering new possibilities for enhanced heat transfer efficiency (Feng et al., 2022).

Triply periodic minimal surfaces (TPMS) are geometric structures with remarkable properties, characterized by minimal surface area. Leveraging the unique features of TPMS, designers have begun to incorporate these structures into the layout of shell and tube heat exchangers. By utilizing TPMS, it becomes possible to create intricate three-dimensional shapes within the heat exchanger, effectively increasing the heat transfer surface area while minimizing the material requirements (Rast, 2021).

The incorporation of TPMS in shell and tube heat exchangers holds significant promise for optimizing heat transfer performance (Reynolds, 2020). Through careful selection of TPMS geometries, designers can tailor the heat exchanger's internal structure to achieve desired heat transfer characteristics. The TPMS elements can be strategically arranged within the shell, creating a tube bundle that maximizes surface contact and promotes efficient heat exchange between the fluid streams (Lai et al., 2021).

To ensure the effectiveness of the TPMS-based design, computational fluid dynamics (CFD) analysis is employed. This simulation technique enables engineers to evaluate fluid flow patterns, heat transfer coefficients, and pressure drop within the heat exchanger. By iteratively refining the TPMS configuration and other design parameters based on the CFD analysis results, designers can optimize the heat exchanger's performance and efficiency (Li et al., 2022).

The utilization of TPMS in shell and tube heat exchanger design represents an exciting frontier, merging advanced geometric concepts with established engineering principles. While the practical implementation of TPMS-based heat exchangers is still evolving, early studies indicate their potential to enhance heat transfer efficiency while simultaneously reducing material usage and pressure drop (Swapneel Shailesh Danayat, 2019).

RESEARCH METHOD

The research is conducted at the thermal engineering lab at universitas singaperbangsa karawang using ntopology for the design and ansys for the simulation.

Research variable

The lattice will be made using gyroid tpms as is proven to most effective in heat exchanger (Alteneiji et al., 2022) It was found that the solid-Gyroid model with larger porosity significantly improved mass transfer and lowered pressure loss (Yeranee & Rao, 2022) and the heat exchanger will be made in shell and tube form because Shell and tube heat exchanger (STHX) is one of the most widely used heat exchangers in industrial applications (Arka & Haider, 2018).

Research step

- Literary study
  Finding the suffient research paper for this particular subject
- Designing the cad
  The design phase will take place using ntopology
- Analysis
  The analysis will be conducted using ansys fluent

Result and explanation the design made from ntopology based on an oil cooler and meshing will be

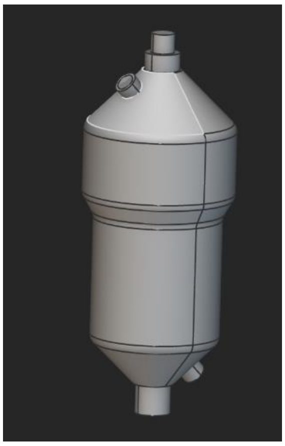


Figure 2 oil cooler design

done within the ntopology software this help ensure mesh integrity we also need to determine the cold fluid to solid interface for further simulations.

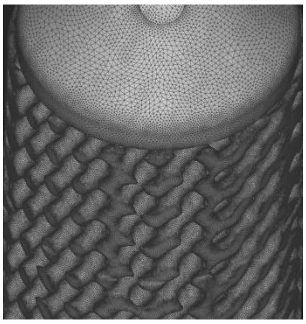


Figure 1 Ntopology Mesh

After this we need to put the boundary in ansys spaceclaim.

Figure 3 Spaceclaim

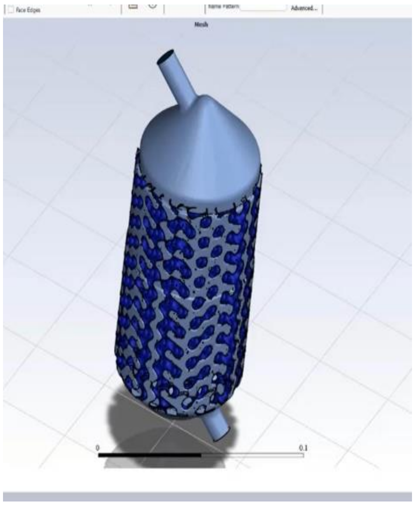
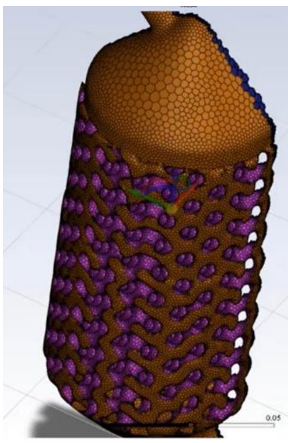
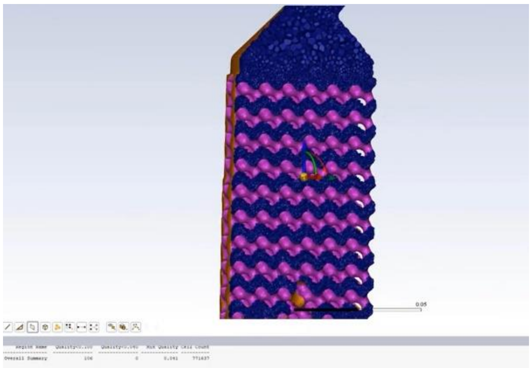


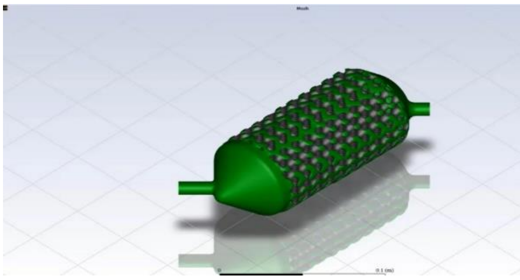
Figure 4 Fault Tolerant Meshing

The design made from ntopology based on an oil cooler and meshing will be done within the ntopology software this help ensure mesh integrity we also need to determine the cold fluid to solid interface for further simulations after this we need to put the boundary in ansys spaceclaim then we open ansys fluent with the Fault tolerant meshing workflow then we generate the volume mesh.

The result is a polyhedral infill with 7771637 cell count.

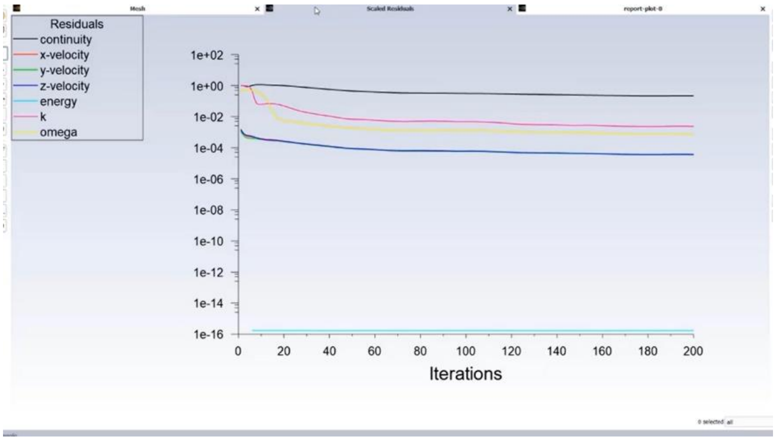






Then we run the simulation using the energy equation in ansys with mass flow rate 0.45kg/s and total temperature at 302 k at the inlet and outlet (Bergman et al., 2011).

Below is the graph of the simulation result.



After a minimum of 200 iteration the simulation finally converge and comparing with convtional design we achive the following the comparison is made between a generic fuel cooled oil cooler (GEBRU, n.d.) and the tpms.

Table 1

	Total Surface Area	Total Effective Surface Area	Pressure Drop
Conventional	-7.82E+05mm^2	4.15E+05mm^2	1300 Pa
Tpms	-1.06E+06mm^2	-1.06E+08mm^2	210Pa

CONCLUSION

The tpms has increased the surface area by 26%, the total effective surface area by 60 percent and a significant decrease in pressure drop the TPMS also maximize surface area for a given volume, improved flow dynamics and high strength self supporting geometry.

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