COMPUTATIONAL HEAT AND FLUID FLOW ANALYSIS OF AN INNOVATIVE PLATE FOR A PLATE HEAT EXCHANGER [1]

İnovatif Geometriye Sahip Bir Plaka Tipi Isı Eşanjörünün Numerik Isı ve Akış Analizi

Cenk BÜYÜKAŞIK
Otomotiv Mühendisliği Anabilim Dalı

Mehmet BİLGİLİ
Otomotiv Mühendisliği Anabilim Dalı

ABSTRACT

In this study, heat transfer and fluid flow are numerically investigated for interrupted sinusoidal channels with ANSYS Fluent software under the assumptions of 2D viscous, incompressible, fully developed laminar flow. For this aim, an innovative sinusoidal geometry was created and used. Since the flow was periodically repeated, the periodic boundary condition was used to save computational time. Before the main computations, validations were performed to ensure the accuracy of the solutions. Effects of the sinusoidal wave amplitude, the thickness of the wall, space between interrupted channels, and vertical distances on Nusselt number, friction factor, and thermal enhancement factor were investigated for different Reynolds numbers. Velocity vectors, velocity contours, and temperature contours were also shown. Results from the study shown that this type of channel has increased the Nusselt number and friction factor due to the vortex generation.

Key Words: Sinusoidal channels, heat transfer, flow, the thermal enhancement factor

ÖZET

Bu çalışmada ANSYS Fluent programı kullanılarak kesikli sinüzoidal kanallarda iki boyutlu, viskoz, sıkıştırılamaz, tam gelişmiş laminar akış davranışı numerik olarak incelenmiştir. Çalışma için inovatif sinüzoidal bir geometri oluşturulmuş ve kullanılmıştır. Akış periyodik olarak tekrarladığından hesaplama sürecini kısaltmak adına periyodik sınır şartı kullanılmıştır. Ana hesaplamalar öncesi sonuçların güvenilirliği için validasyonlar yapılmıştır. Sinüzoidal dalga şiddeti, duvar kalınlığı, kesikli çizgiler arası yatay ve dikey boşlukların Nusselt sayısı, sürtünme faktörü ve ısıl iyileştirme sayısına etkisi incelenmiştir. Seçilen geometrinin farklı Reynolds sayılarındaki davranışı gözlemlenmiştir. Hız vektörleri ve hız konturları ile sıcaklık konturları da araştırılmıştır. Çalışmadan elde edilen sonuçlar bu kanal türünün Nusselt sayısını ve sürtünme faktörünü arttırdığını göstermiştir.

Anahtar Kelimeler: Sinüzoidal kanallar, ısı transferi, akış, ısıl iyileştirme sayısı

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[1] Aynı başlıklı Yüksek Lisans tezinden üretilmiştir.

Introduction

Heat exchangers are one of the most utilized devices in the industry. They are widely used in various industrial fields spanning from the automotive sector to heating, refrigeration and air-conditioning sectors with different types and capacities. Beginning from the early 2000s, the heat exchanger industry is affected by the petroleum extinction and global warming threats in such a way that new, more effective designs are compelled by the industries. In today's industry, there are various heat exchanger types from the size of a hand to 25 meters long and 450 tons of weight. The Evolution of heat exchangers started thousands of years ago from homes, and nowadays, it leads humankind to reach interstellar activities. In this study, a new innovative shape of a plate heat exchanger will be examined and compared to the conventional types.

In this study, a new plate heat exchanger geometry is examined. A plate heat exchanger system consists of some numbers of plates aligned together with two diagonal flows within. These flows are separated by plates, as shown in Figure 1.3. The surfaces in flow directions are the places that perform heat transfer. In need of a more compact system such as high-pressure liquids welded, semi-welded, and brazed heat exchangers are used. Instead of the pipe passing through a chamber, there are two exchange rooms, generally thin in-depth, divided at their most prominent facet by a corrugated metal plate. The plates used in a plate and frame heat exchanger are acquired by one-piece pressing of metal plates. Stainless steel is a standard metal for the plaques since it is capable of withstanding high temperatures; also, its strength and corrosion resistance is remarkable. A plate heat exchanger comprises of thin plates that involve small channels. It has two sides of flow that possess different temperatures; by this mentality, the system generates heat transfer. When designing and operating such a system, one must consider the following restrictions. Flow turbulence control, pumping power, dimensions, surface geometry, materials to use both as fluid and the system itself. This study had been dealt with the surface geometry aspect. Some experiences inspired this work here is some necessary information regarding this study.

Regenerating the boundary layer to enhance the heat transfer and increasing the surface area in which the heat transfer happens, creating mixing regions to generate higher heat transfer coefficients are plausible for higher values. To reach this idea, the approach of converging and diverging channels is new innovative thinking.

These channels lead to higher surface areas in unit volume and create larger mixing spaces, which considered to be led to higher heat transfer. Pressure drop and mass flow rate need to be contemplated since a drop in these concepts is somehow expected. The real aim of this work must be figured out for the system, and the optimal specifications should have been implemented to achieve the best results.

Heat and flow characteristics of converging and diverging channels are bound up with many parameters as plate size, plate thickness, the distance between plates, plate attack angle, plate temperature, and Reynolds number.

The CFD technique was used to solve the suggested situation. CFD is a branch that uses computer programs, which include a mathematical background and various algorithms to work out and/or analyze a flow problem. The program divides the examining element or system into small meshes and iteratively solve the flow problem for each grid. This approach would lead to very precise solutions if the boundary conditions identified, the meshes generated appropriately, and the solutions interpreted. In this study, ANSYS Fluent is used to solve the problem. At first, the "Space Claim" interface operated to draw the geometry than proceeded the "Meshing," and after proper progress, the file opened with the Fluent to initiate the analyses.

Material and Method

In this study, CFD is used to analyze an innovative plate's behavior under different geometry parameters. The flow is under the assumption of 2D, laminar, incompressible, viscous, and fully developed.

The flow in a tube can be laminar or turbulent, depending on the flow conditions. The Reynolds number provides a convenient criterion for determining the flow regime in a tube, although the roughness of the tube surface and the fluctuations in the flow have considerable influence. The critical Reynolds number for flow in a tube is generally accepted to be 2300. Therefore,

Re<2300	laminar flow
2300≤Re≤4000	transition to turbulence
Re>4000	turbulent flow

Convective Heat Transfer Inside Tubes

Energy is transferred from a surface to liquid streaming over it because of the temperature difference between the surface and the fluid, called convection. The convective heat transfer rate depends on the specifications of the flow field.

If the temperature at some point on the surface is T_w and if the rate is being transferred locally at this point from the surface to the liquid per unit surface area is *q*, then it is usual to define a quantity, *h*, such that:

$$q = h(T_w - T_f)$$

It is appropriate to determine the *mean temperature difference* between the wall and the flow as:

$$\Delta T = (T_w - T_m)$$

This study numerically analyzes a specific geometry using the CFD method, as it has mentioned at the beginning of this chapter. First, the geometry identified afterwards the method applied to define the behavior under some variable parameters.

Computation Area and Parameters Affect the Problem

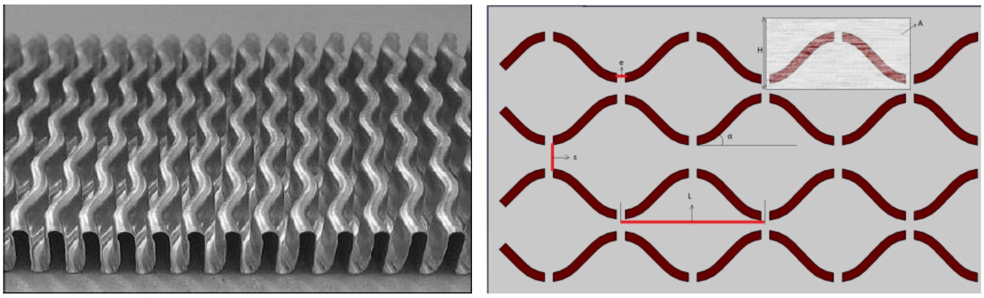


Figure 1. Representative pictures of the wavy passages and solution area

This study deals with the converging and diverging channels from a different point of view, wavy or sinusoidal channels. Figure 1 is a representative picture of imagination. For this problem, heat transfer performed with forced convection through these channels will be examined. A 2D representation for this subject shown in figure 1.

Wave Amplitude Definition and Wave Drawing

Wave amplitude frequently mentioned and a big part of this study. This object based on a cosine wave, which is shown in figure 3.4. It had been drawn in space claim with the help of the equation interface. The Wave amplitude represents a cosine wave amplitude.

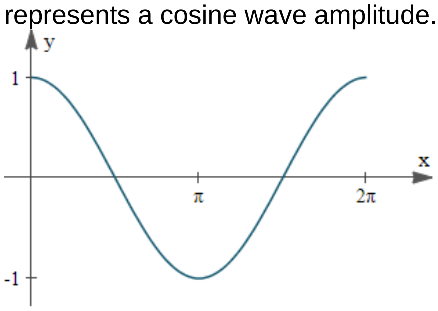


Figure 2. Cosine wave representation

Results and Discussion

Wall Thickness Investigation

Two different thickness values had been examined for this study. Thickness values are 1 and 3 millimeters. Sharp shaped, four different wave amplitude geometry with the same internal space of 5 mm investigated. With an increase in wave amplitude, the Nusselt number increases. The friction factor increases with wave amplitude, as well.

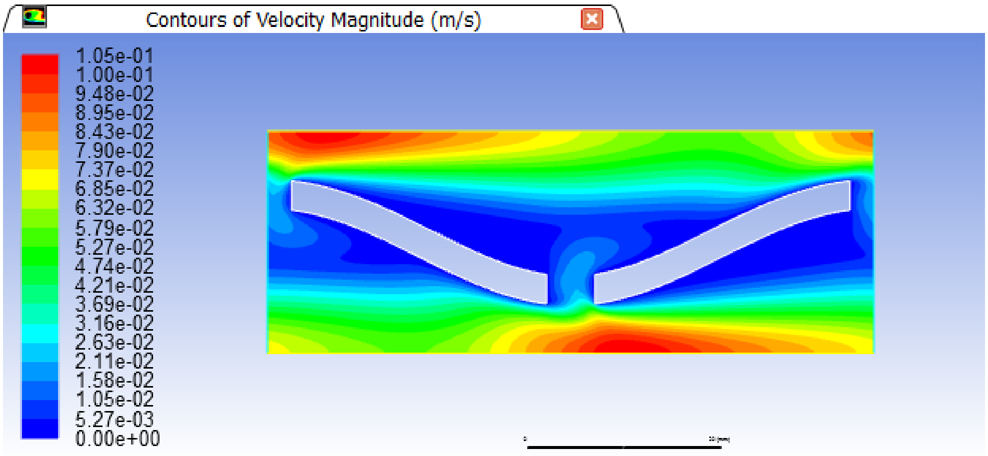


Figure 3. Wall thickness effect on velocity contour representation

After the sharp edge results, an idea of augmenting the aerodynamic structure is considered. Due to this idea, the corners of the wall had been reconstructed as a curve. About 20% - 25% change is observed as a gain for Nu number due to radius edge usage.

Internal Space Investigation

One of the main aims of this study is to look through the sinusoidal abrupt walled innovative plate behavior under some defined parameters. The following chapter compares distributions of Nu and f values for each wave amplitude. There are four different wave amplitudes and three different internal edge spaces. After that comparison, the best geometry will be examined in different ways.

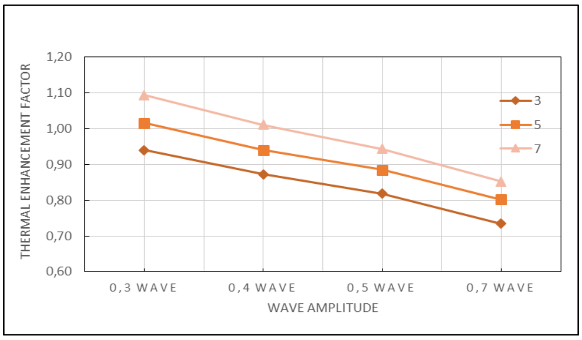


Figure 4. Efficiency values for Wave amplitude with respect to Internal Edge Space

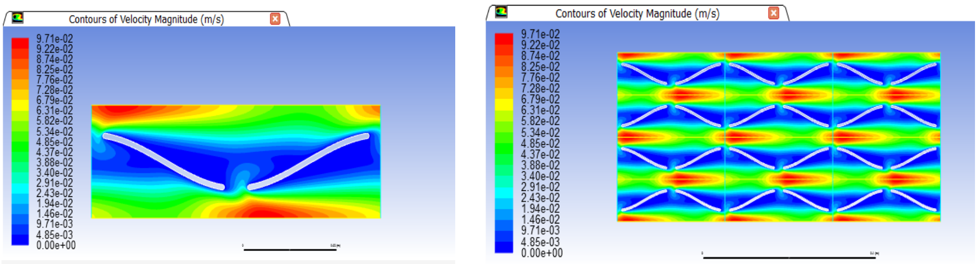


Figure 5. Velocity contours of the geometry with internal edge space

Vertically Interrupted Values

Velocity contours (figure 4.40 and figure 4.41) show the flow separation, and this process provides the regeneration of the boundary layer, which increases the heat transfer. Temperature contour (figure 4.42) displays the heat increment around the sinusoidal walls.

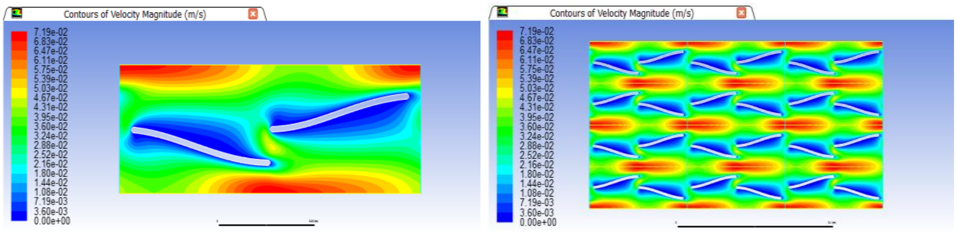


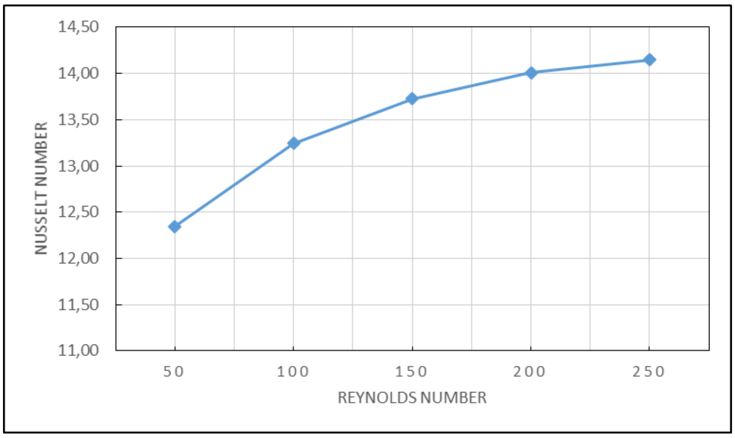
Figure 6. Velocity contours of the geometry with vertical edge space

The velocity is higher in vertically interrupted wave geometries than the normal pattern. This process highly affects the boundary layer regeneration and provides better heat transfer, which also numerically validated.

Reynolds Number Effect

Ultimate geometry among the researched interval is found as 0.3 Wave amplitude, 5 mm vertical distance, and 7 mm internal edge space. Figure 4.49 shows the increment of the Nusselt number with a raise in the Reynolds number. Table 4.23 is a consolidation for Nusselt number, friction factor and thermal enhancement factor versus Reynolds number increment.

Re	Nu	f	η
50	12,34476	5,52999	1,15072
100	13,24516	3,10730	1,18754
150	13,72768	2,27792	1,19245
200	14,00952	1,85027	1,18501
250	14,14825	1,58564	1,16961



Conclusion

In the first section, a validation process performed to assure the accuracy of the further results. In the second section, the thickness effect for sharp-edged wavy walls had been investigated. In the third section, the radius intercalated edges effect investigated concerning sharp edges for different wave amplitudes under the circumstances of thickness t=1mm and Reynolds number of 100. In the fourth section, internal space edge variety effect on performance, investigated for three different values, which are 3, 5 and 7. In the fifth section, interrupted waves have been investigated. A vertical distance is implemented. performed best for this investigation among the others. In the last section, the best geometry had been chosen among 70 analyses. At first, the last part of the induction is executed. Nu,f, and η values compared for 0.3 wave amplitude 5mm vertical distance for internal edge spaces of 3,5 and 7 mm.The 3D version of this study might be a further research idea. Also, the results can be validated empirically and an experimental study can be performed. In addition to that, the turbulent version of the analyses can be conducted to reach more precise results. These are the future ideas which this work will lead.

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