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# A PAPER ON TUBULAR HEAT EXCHANGER WITH JET IMPINGEMENT COOLING

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**Abstract:**
A heat exchanger is a system that transfers heat from one source to another. Heat exchangers are employed in the heating and cooling processes. The fluids might be in touch with one another or isolated from each other by a solid wall to prevent mixing. They are extensively used in power plants, chemical and petrochemical facilities, sewage treatment facilities, natural gas processing, power plants, and space heating, refrigeration, and air conditioning. The most common form of heat exchanger used in oil refineries and other large chemical processes is the tubular heat exchanger, which is also the most economical. These heat exchangers are ideally suited for high-pressure applications. As the name suggests, this type of heat exchanger consists of a large pressure vessel shell with a tube within. One fluid passes through the tubes while another fluid streams over them (via the shell) to transfer heat. Thus, in order to improve the overall efficiency and heat transfer of shell and tube heat exchangers, we have conducted research on a novel design that incorporates the jet impingement approach.

**Keywords**: Heat Exchangers, Jet Impingement cooling, Tubular heat exchanger.

## 1. Introduction

Tubular heat exchangers are very cost efficient and are used in multiple industries. On the other hand Jet impingement cooling is a technique used to efficiently cool surfaces or components by directing high-velocity jets of a cooling fluid onto them. This method is widely used in various industrial applications, especially in electronics cooling, gas turbine blade cooling, and high-performance computing systems. Fluid, often air or liquid, is ejected from a nozzle or an array of nozzles onto the surface which is to be cooled. The jets strike the surface directly, creating localized high heat transfer rates due to increased turbulence and mixing of the boundary layer. The convective heat transfer coefficients achieved through jet impingement are higher compared to other cooling methods, facilitating efficient heat dissipation. Jet impingement cooling, while highly effective, requires thoughtful engineering to balance its benefits with considerations like system complexity and fluid dynamics. Nonetheless, its ability to provide efficient and targeted cooling makes it a valuable technique in various industries.

This paper is related to mechanical industry. This method can be basically used in increasing the rate of heat transfer in tubular heat exchangers using jet impingement method, Which can be significantly more effective than normal heat exchangers.

## 2. Prior art:

Many researchers have gone through the study of Jet impingement in cooling on flat surface, but here we have studied jet impingement in shell and tube heat exchanger where the targeted surface is a circular tube. The major aim of this paper is to research on the heat transfer rate occurred due to jet impingement in a tubular heat exchanger which may significantly increase the heat transfer rate. Flow stagnation is the main cause of the improvement of heat transfer. Although the efficiency of jet impingement as a cooling mechanisim is widely established the complexity of manufacturing processes to readily incorporate impingement systems into cooling designs has limited its application to a variety of difficulties. The effectiveness of impingement thermal transfer can be boosted further by altering the jet holes, boosting surface characteristics and modification in design. With greater use of this cooling approach and subsequent geometric modifications to further improve heat transfer capacity to suit varied applications. For a variety of heat transfer improvement applications, Here we will have a look into impingement cooling across a range of modification with an emphasis on influencing new design and implementation.

**3. Jet Impingement cooling:**
To improve the shell's and tube heat exchanger's functionality we have came up with impinging jets in it, Impinging jets may significantly boost heat transmission in industrial applications. Numerous flow phenomena, such as large-scale structures, enormous curvature involving significant shear and normal stresses, stagnation in the structure's boundary layers, transfer of heat with the impinged wall, and small-scale turbulent mixing, can be caused by the impinging flow. These occurrences are all very irregular and despite the fact that a substantial number of studies have been dedicated to them in the literature, Because of their extremely unstable nature and the difficulties of conducting in-depth computational and experimental examinations, impinging jets remain mostly unknown. The heat transmission in heat exchangers made from tubes and shells will increase as a result of this study.

**4. Literature Review:**
N. Zuckerman et. al. [22] stated that a submerged impinging jet's flow traverses many separate zones, The upstream flow determines the jet's velocity, temperature profile, and turbulence characteristics as it emerges from a nozzle or aperture. A minor degree of turbulence develops upstream along with the flow developing into the parabolic velocity distribution typical of pipe flow in a pipe-shaped nozzle, also known as a tube-shaped nozzle or cylindrical nozzle. In contrast, an initial flow with a relatively flat velocity profile, minimal turbulence, and a flowing downstream contraction will be produced by applying differential pressure over a thin, flat orifice. Conventional jet nozzle designs employ either a long, narrow jet that features a 2D flow profile or a spherical jet that has an axisymmetric flow profile. The emerging jet may go through an area after it leaves the nozzle where it is far enough away from the impingement region to act as a free immersed jet. In this instance, the jet's velocity gradients cause a shearing at its edges, which transmits momentum laterally outward, bringing more fluid with it and increasing the jet mass flow. The process results in the jet losing energy and the velocity profile along the jet's sides decreasing in amplitude and widening in geographic area. Reducing these additional pressure losses is one aspect of enhancing the overall performance of jet impingement devices. These losses originate from various parts of the flow path.
Weigand et. al. [21] jet impingement systems may reach high transfer of heat and mass rates, they offer an efficient way to improve convective processes. Impinging jets have an extensive variety of industrial applications in use today. Impinging jet technologies are used for drying paper and textiles, as well as for chilling heated materials such as plastic, metal, or glass sheets. Compact heat exchangers are used in the automotive and aerospace industries, and they frequently employ dense arrangements of many impinging jets. Impingement systems are frequently utilised in microscale applications to cool semiconductor chips and other electronic components. Jet impingement has become a common practice in gas turbine uses for a long time. Demands for lower emissions, more power production, and better efficiency are placing requirements on the system. By raising the compressor ratios and turbine inlet temperatures, high thermal efficiency may be achieved. This leads to the operation of various gas turbine parts, including rotor discs, turbine blades and vanes and combustion chamber walls, at temperatures far higher than the maximum permitted material limits.
The flow and heat transmission properties of numerous impinging jets can vary significantly from single jets, mostly due to geometeric circumstances. Two main types of interactions that do not happen in a single jet system can have an impact on each individual jet in a multijet setup. Before the jets impact on the target plate, there may be a jet-to-jet contact between neighbouring pairs of jets. Second, there is the interaction between the jets that are impinging and the flow created by the jets that are

nearby that have expended their air. Large velocities, short separation lengths, and narrow interjet spacing are the main causes of these disturbances in arrays.

Sagot et. al. [16] carried out experimental setup for impinging jet on a hot gas jet on a cold plate, heated in a coaxial exchanger to provide a steady jet temperature, and a regulated air flow rate provided by a compressed air unit. Depending on the Reynolds number, the fixed gas jet temperature during the studies ranged from 40°C to 65°C. The heat flux transferred within the hot jet and the cool plate ranged between 10 and 60 W during the study's operating circumstances.A water circulation within the cooled block that supports the impingement plate maintains the proper temperature. To maintain a constant and even temperature on the impingement plate, a high flow rate of a cooling fluid with a controlled temperature (stability: 0.02°C) is utilised.
An aluminium plate with a thickness of 3 mm and conductivity of 210 W.m1.K1 serves as the impinging surface. At the plate border, below the stagnation point, and one mm below the impact surface, two thermocouples are installed. These thermocouples' measurements verified the homogeneity of the surface temperature, with the highest possible variation of around 0.5° between the plate border and the stagnation point. The actual wall temperature on the surface is calculated with a correction factoring in the plate's electrical resistance. This adjustment stays less than 0.2°C because of the cooled plate's low thermal resistance. Nearly 4°C was the wall temperature throughout the studies.
While the local heat flux cannot be determined by this experimental approach, the mean wall coefficient of heat transfer may be determined by simultaneously measuring the mass flow rate m.

**5. Synopsis:**
This analysis is carried out using flow simulation in solidworks software. Jet impingement methods are employed for excessive amounts of HT in several domains. The Reynolds value, the form of the target surface, the distance among the jet injector and the desired surface, expanded jet holes, the usage of nanofluids and jet thermal dissipation are some of the variables that influence how rapidly heat is transported by an impinging jet. So as mentioned we have added jet impingement in tubular heat exchanger, as we know tubular heat exchangers consist of a shell and a tube so here the modification is done in the shell as there is no change in tube, we have added jet impingement on the top surface of the shell, here the targeted surface is the surface of the tube so as the jet is sprayed is over the tube using nozzle, the cold liquid is directly bombarded on the tube surface (containing hot fluid) through multi-jets which helps in faster HT rates here as the fluid is sprayed through the nozzle on the impingement surface helps in increasing the heat transfer rate.

**6. Jet impingement in shell and tubular heat exchanger Analysis:**
Jet impingement cooling works by splashing a working fluid onto a heated surface. With a rise in the quantity of jets , the possibility to cover a bigger area as well as increase the total amount of fluid shot onto the heated surface is introduced. All the design is carried out with the help of Solidworks software. We have induced maximum no. of jets (multi-jet) i.e 14 in the design of heat exchanger. When compared to a single jet, this increase in no. of fluid flow causes the transfer of heat to increase throughout the entire region and can be considered as a benefit for larger heated surfaces. The properties of heat transmission in a jet impingement setup using jet holes are examined in several researches.There is an inline array of the jet openings in the jet line. The submerged impinging jet's flow passes through numerous separate areas. The jet leaves from an opening at a certain speed, temperature, and turbulence determined by the upstream flow. An individual jet's flow pattern is composed of three separate regions: free jet, stagnation point and wall jet region. The area where a free jet operates arises from the nozzle and positioned a long distance away from the desired surface. The outgoing jet's interaction with its surroundings, driven by shear, creates mass, momentum, and energy absorption in this region.

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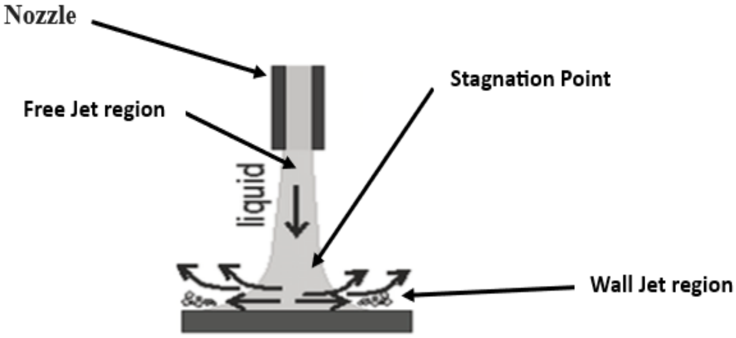


**Figure.1** Liquid splashing from the jet nozzle over targeted surface.

There are several variables to consider, including nozzle shape, velocity profile, jet and target tube placing. The jet exits from the nozzle and is sprayed on the tube from fourteen different nozzles resulting in increased heat transfer rate. The turbulence level influences the HT that exists between the jet impingement along with the desired surface. The stagnation point is the point at which HT reaches its maximum, after which HT rates decrease radially.

## 7. Experimental Analysis and Results:

As we have introduced jet impingement cooling in tubular heat exchanger we have studied its heat transfer using Solidworks flow simulation.

Ethylene and water are the two fluids used. 0.001 kg/s(Inlet mass flow) of Ethylene is the hot fluid passing through the circular tube at 80 degree celsius with velocity of 0.006 m/s at pressure 101325 pa, while water is passed through the impingement jets at 10 degree celsius at velocity of 10 m/s. The turbelence taken into consideration is 2%.The mole fraction taken for water and ethyene were 0 and 1 respectively. For higher heat transfer rate copper is used as a metal for heat exchanger.

Here the cold fluid i.e water's inlet passing temperature was 10 deg. and hot fluid ethylene's inlet stream temperature was 80 deg. after the heat transfer takes place the outlet temperature of ethylene stream was dropped down to 49.95 degrees and the outlet temperature of water stream was 10.29 degrees.

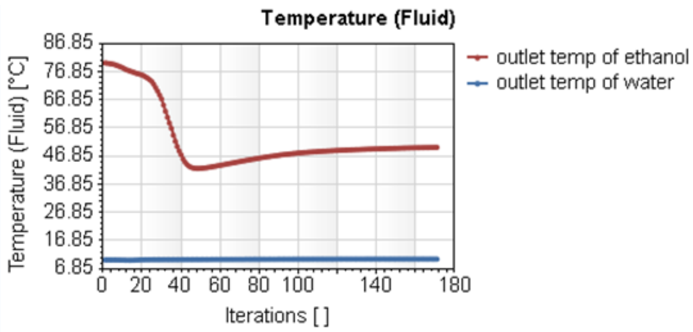


**Figure.2** Temprature v/s Iteration Graph

| Goal Name | Unit | Value | Averaged Value | Minimum Value | Maximum Value | Progress [%] | Use In Convergence | Delta | Criteria |
|---|---|---|---|---|---|---|---|---|---|
| outlet temp of ethanol | [°C] | 49.95 | 49.66 | 49.30 | 49.95 | 100 | Yes | 0.65 | 1.12 |
| outlet temp of water | [°C] | 10.29 | 10.28 | 10.28 | 10.29 | 100 | Yes | 0.01 | 0.01 |

Model | 3D Views | Motion Study 1 | **Goal Plot 1**

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**Figure.3** Max. and Min. Temperatures of both fluids showing other data.

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| Goal Plot 1 | |
|---|---|
| outlet temp of ethanol | 49.95 °C |
| outlet temp of water | 10.29 °C |

**Figure.4** Temperature at outlet

**Conclusion:**

This Proposed article addresses the experimental analysis related to heat transfer occuring in tubular heat exchangers due to jet impingement cooling. Jet impingement cooling in shell and tube heat exchangers have been very effective, since it has enhanced heat transfer rates by directing high-velocity jets onto the tube surface, heat transfer rates increase significantly due to fluid mixing, which results in more effective heat exchange. By using impinging jets we were able to bring down the temperature of the hot fluid from 80 deg. To 49.95 degrees. Jet impingement allows for a more compact design of heat exchangers by enabling higher heat transfer coefficients. The enhanced heat transfer capabilities of jet impingement resulted in improved efficiency of the heat exchanger, allowing for better utilization. Jet impingement provides better control over fluid flow patterns, which can be optimized to suit specific heat transfer requirements and improve overall system performance. Higher fluid velocities associated with jet impingement can help reduce fouling on the tube surface by preventing the buildup of deposits or contaminants, thus improving the heat exchanger's operational efficiency. Jet impingement can be used with various fluids and in different industries, making it a versatile technique applicable across a wide range of applications. Until now there have been many studies performed on jet impingement. Jet impingement has significantly shown high heat transfer rate, Hence we can say jet impingement in heat exchangers can be proven effective.

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